SENSORS & CONTROLS

Project Fact Sheet

LIGHT-SCATTERING-BASED SENSOR FOR ON-LINE MONITORING OF FIBER DIAMETER DISTRIBUTION DURING MANUFACTURING

BENEFITS

- The sensor is designed to provide in-situ, real-time measurement of the diameter distribution as fibers are produced. No other instruments are currently available for such on-line applications.
- The sensor would be useful as a process monitor during fiberglass manufacturing to avoid production of fibers with a high number of diameters outside of the desirable range.
- The sensor would provide timely information on fiber diameter changes to the operator, with the potential for future use in closed-loop process control systems.

APPLICATIONS

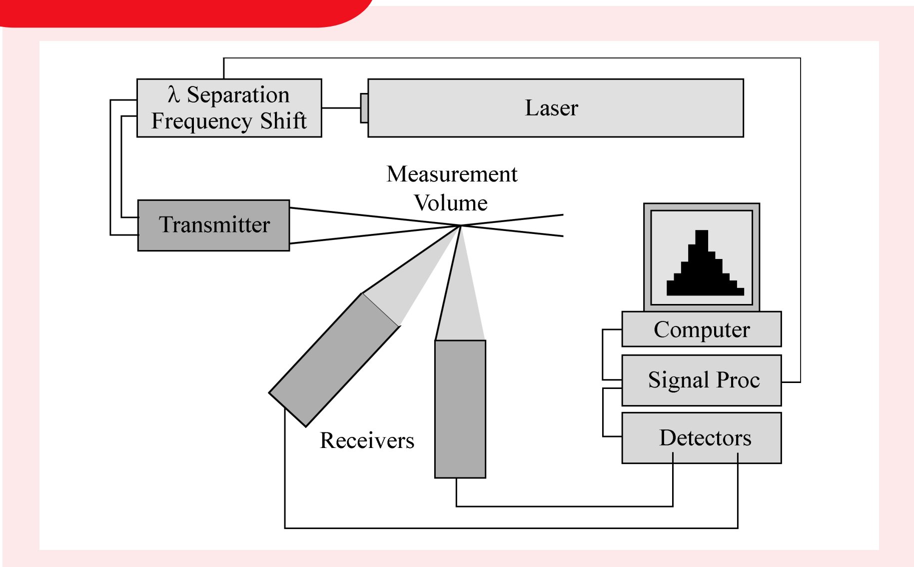
- On-line monitoring of fiber diameters would allow both glass and synthetic fiber manufacturers to maintain high productivity while avoiding the inferior product quality associated with broad fiber diameter distributions.
- The interferometric phase/Doppler device could also provide high resolution, on-line diameter measurements for aligned, large diameter fibers.
- A tool for on-line monitoring of fiber diameter distributions would be useful in research and development efforts in fiberglass manufacturing industries.

THIS TECHNIQUE COULD ENABLE THE FIRST ON-LINE MEASUREMENTS OF FIBER DIAMETER DISTRIBUTIONS IN THE FIBERGLASS AND OTHER FIBER INDUSTRIES

The diameter distribution of fibers plays an important role in the performance of many fiberglass products. Key performance issues related to fiber diameter include thermal insulating performance, tensile strength, and product stiffness. In addition, knowledge of diameter distribution is important for evaluating product health risks such as inhalation and skin irritation. Despite the importance of these measurements, the fiberglass industry lacks the advanced instrumentation necessary for performing on-line fiber diameter measurements. Enhanced measurement capabilities would provide manufacturers and researchers with a tool to improve fiberizing methods, production efficiency, and overall fiberglass product performance.

This research combined both experiment and theory to address the design, laboratory testing, and field evaluation of a light-scattering-based sensor, optimized for on-line fiberglass diameter measurements. The measurement technique is based on modifications to phase/Doppler technology that has been used successfully for small diameter aerosol measurements. The technology is intended for use in monitoring changes in fiber diameters during the rotary fiberizing process, but it should also be applicable to other fiber production methods.

FIBER MEASUREMENT SYSTEM



The fiber measurement system illustrated above could be the first instrument available for in-situ, real-time measurement of fiber diameter distribution.

Project Description

Goal: Develop a sensor using light-scattering methods for on-line fiber diameter distribution measurements.

This project developed a new, light-scattering-based fiber diameter sensor for use in the fiberglass and other fiber industries. The sensor measurement technique is based on modifications to the phase/Doppler technology that has been used successfully for small diameter spherical aerosol measurements. The sensor illumination source is a coherent laser, which is split into two incident beams that are focused and crossed at a common measurement volume, producing a series of light and dark fringe planes. One of the incident beams is phase shifted using a Bragg cell, so as fibers pass through the measurement volume, a modulated scattered light signal is produced, collected, and processed by the system.

Theoretical modeling used the mathematical solution for a tilted circular cylinder interacting with focused laser beams. The theoretical model accounted for the optical components and geometry of the measurement system and was used to simulate instrument response for a range of candidate experimental configurations. Experimental laboratory studies using fiber samples were conducted to evaluate those factors not included in the theoretical model such as signal processing requirements.

Field evaluations of the fiber measurement system occurred at two production plants. Although changes in mean fiber diameter were tracked successfully, a reliable measure of the width of diameter distribution could not be obtained. The test results underlined the significance of light scattering by ensembles of fibers, which were not taken into consideration earlier.

Additional partnerships have been established to help account for ensemble light scattering effect and for extensive testing of the commercial version.

Accomplishments

- The Phase I project was selected through a FY96 Small Business Innovation Research (SBIR) solicitation and was completed in six months. The Phase II project, awarded in FY97, was completed in FY99.
- A state-of-the-art computer code was developed and implemented for theoretically modeling the response of the phase/Doppler system to tilted, cylindrical fibers.
- Theoretical modeling and experimental testing were used to identify the phase/Doppler optical configurations that provide the best measurement performance.
- Field tests of the phase/Doppler system were conducted on a rotary fiberizing unit. Changes in mean fiber diameter, consistent with off-line measurements and physical expectations, were successfully monitored on-line.
- The work for this project resulted in the following publications:
  1. “An Interferometric Optical Instrument for In-Situ Measurement of Fiber Diameter,” *Particle and Particle Systems Characterization* **16** (3), 128-134 (1999).
  2. “Development of a Generalized Theoretical Model for the Response of a Phase/Doppler Measurement System to Arbitrarily Oriented Fibers Illuminated by Gaussian Beams,” *Applied Optics* **37** (33), 7842-7855 (1998).
  3. “Design of a Phase/Doppler Light-Scattering System for Measurement of Small Diameter Glass Fibers During Fiberglass Manufacturing,” *Applied Optics* **37** (3), 573-585 (1998).
  4. “Progress in On-Line Fiber Diameter Measurements,” special issue on Sensors for Glassmaking, *Glass Researcher* **8** (2), 18-20 (1999); republished in *Glass Machinery, Plants & Accessories* **5**, 124-128 (Sept/Oct 1999).

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December 2000